54

SOME STUDIES ON THE SPREAD-F, DOUBLE-F AND FORKED-F TRACES AS OBSERVED AT HARINGHATA (CALCUTTA)

R. N. DATTA

INSTITUTE OF RADIOPHYSICS AND ELECTRONICS, UNIVERSITY OF CALCUTTA, CALCUTTA-9

(*Received, August* 19, 1960)

ABSTRACT. The paper deals with the occurrence and origin of the Spread-F phenomena including 'double' and 'forked' F-traces. From the spread-F records and from the theoretical relation of the spread-F index with the criticleal frequency and the velocity of irregularities, it is found that the percentage of occurrence of spread-F depends both on the electron density and the velocity of the irregularities. The night-time appearance of this phenomenon and its sharp decrease at sunrise lend support to this conclusion.

INTRODUCTION

Irregular and diffuse reflections from the night-time F layer, commonly known as the spread-F or F-scatter phenomena, have received considerable attention in recent years particularly in relation to its diurnal and seasonal variations and its dependence on magnetic activities. In this paper, a study of the the spread-F phenomena has been made from the $h'-f$ records of Haringhata (Geomag. lat. 12.5°N, long. 88°31′E, lat. 22°56′N) for low sunspot years 1955-56, and the characteristics obtained at this latitude are compared with those reported from other places. Theoretical consideration on the origin of spread-F and its relation with F_2 region irregularities have been examined.

The study of the observed characteristics includes diurnal and seasonal variations of the nature and occurrences of spread-F in different seasons and on magnetically quiet and disturbed days. An index of scale zero to three as suggested by Briggs (1957) has been followed for indicating the degree of spreading (scale zero refering to normal trace and scales one, two and three to the weak, medium and intense types of scattering respectively). The relations between f_0F_2 with the occurrence of spread-F and its latitude variation have also been discussed. A study of the nature and occurrences of double-F and forked-F traces has been made, as, both the said traces are usually found to precede or follow the scattering phenomena. According to Briggs (1957), the spread in critical frequency is due to the presence of the ionospheric irregularities in the F region and according to Voge (1955) these irregularities are dependent on the velocities. It is shown that if account is taken of both these factors, that is, when the velocity term is included in the expression for the spread in critical frequency, the characteristics of the diurnal and seasonal variations are better understood.

CHARACTERISTICS OF THE SPREAD-F PHENOMENON

The night-time F echoes in the ionograms, leaving aside the simple traces can be classified broadly into three types : (a) Spread-F, (b) Double-F and (c) Forked-F traces (Fig. 1).

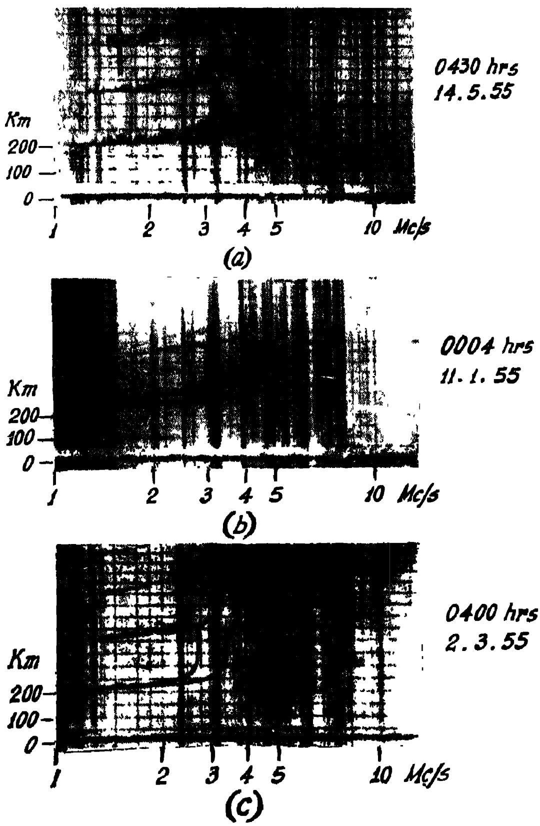

Fig. 1. Typical h'-f record obtained at Haringhata showing
(a) Spread-F,
(b) Double-F,
and (c) Forked-F traces.

(a) *Spread-F trace* : This is a thickening and diffusiveness of both the O and X components of the regular F-echoes which become more marked near the critical frequencies. Appearing at any part of the night, usually some time after sunset, it becomes more prominent with the progress of the night and decays sharply at sunrise. During the same night the variation in the degree of the spread may pass through one or two peaks. The spread also exhibits seasonal variations in the frequency of occurrence. There is a general agreement in the diurnal variations in the degree of spread obtained at different stations, but the seasonal variations as reported from different places appear to be different. From the analysis of data done by Reber (1954), Briggs (1956), Kasuya *et al.* (1955), Wells (1954), Dagg (1957), Wright *et al.* (1956) and Lyon *et al.* (1958), it is found that leaving aside the auroral type of spreading, the characteristics of spread-F are of two types, namely, (i) middle or temperate lattitude type and (ii) low latitude or equatorial type. The occurrences of temperate latitude type of spreading have a tendency to increase during winter whereas those of equatorial type increase during summer in low sunspot years. McNicol and Bowman (1957), after examining the data for a number of stations, observed that a reasonable smooth distribution of occurrences of spread-F exists in the range of geomagnetic latitudes between 20°N or S and 45°N or S, and that the existence of equatorial type is comparatively small. No suggestion for the change over latitude from equatorial to temperate latitude type of spreading has been given there. Lyon *et al.* (1958) from a study of spread-F and magnetic activity suggested, from the results of two stations, Karoaia and Johanesburg, situated at the temperate latitudes, that the transition from equatorial to temperate type of spreading is at some latitude between these two stations and at about 20°S (Geo. lat.) or 35°S (Geomag. lat.). Recently Kotadia (1959) after examining the data of some northern stations has suggested the change over latitude to be at 31.2°N (Geo. lat.). But the suggested belt for the types of spreading cannot explain the non-seasonal variation of the occurrence of spread-F at Washington (50.3°N Geomag. lat.) and at Rarotonga (21.7°S Geomag. lat.). In our case, however, it is found that percentage of occurrence of spread-F traces, of all the three degrees, is more marked in summer than in winter and is minimum during the *autumnal equinox.* The observational results are depicted in Figs. 2(a), (b), (c) and (d).

Hourly per cent counts of spread-F occurrence have been made separately for the magnetically quiet and disturbed days from the Haringhata data for the summer season in the low sunspot year 1955-56. Variations of the counts are shown in Fig. 3. It will be seen that percentage of occurrences is higher on the magnetically cally quiet than on the disturbed days. Similar effect, i.e., decreased scatter with increased magnetic activity, has been observed for summer at Ibadan (Geomag. lat. 10.4°N), Kodaikanal (Geomag. lat. o.6°N), Singapore (Geomag. lat. 10°S) and Ahmedabad (Geomag. lat. 13.6°N).

Some anomalies also exist regarding the occurrence of spread-F echoes in relation to f_0F_2. Reber (1954) at Hawaii found a clear inverse correlation, whereas Dagg (1957) did not find it as clearly at Slough. The night-time f_0F_2 and its association with spreading phenomena has been studied for Haringhata. The critical frequencies are grouped as shown in Table I and in each range of frequencies, percentage of occurrences of spread-F has been observed.

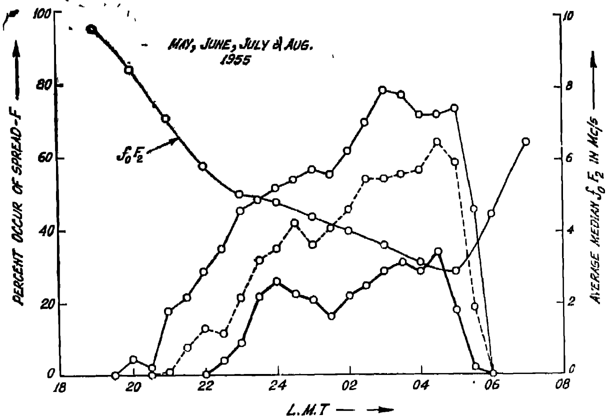

Fig. 2 (a). Diurnal variation of percent count of occurrences of spread-F in summer. ..... weak, --- medium, • • intense.

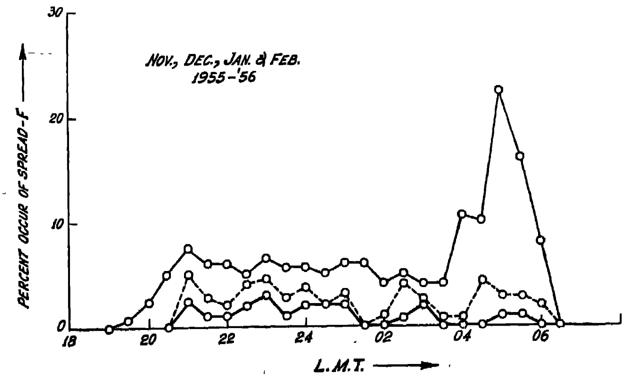

Fig. 2 (b). Diurnal variation of percent count of occurrences of spread-F in winter. ......weak, —— medium, ━━ intense.

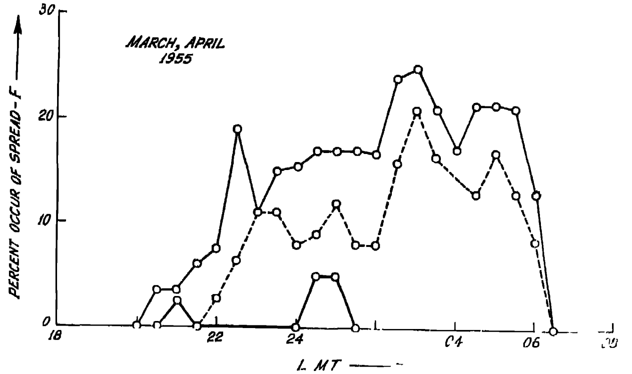

Fig. 2 (c). Diurnal variation of percent count of occurrences of spread-F, in vernal equinox.
......weak, ——— medium, ━━━ intense.

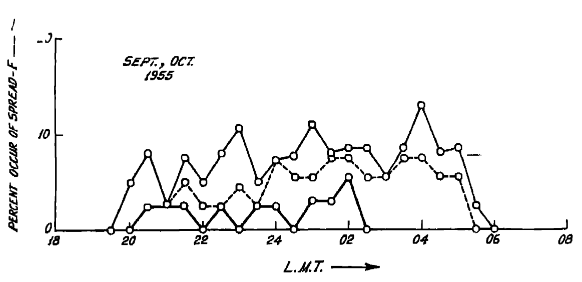

Fig. 2(d). Diurnal variation of percent count of occurrences of spread-F for Haringhata for the three different degree in autumnal equinox.
......weak, ——— medium, ━━━ intense.

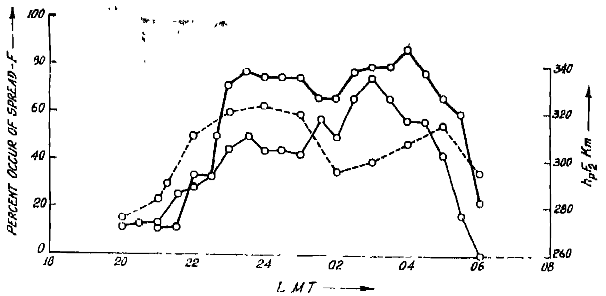

Fig. 3. Diurnal variation of percent count of occurrences of spread-F for magnetically quiet and disturbed days and variation of hourly median values of h_pF_2 at Haringhata. Heavy line represents mag. quiet days light line represents mag. disturbed days and dashed line represents h_pF_2.

TABLE 1

Frequency range in Mc/s	Percentage of occurrence of spread F
1.5—2.0	84
2.1—2.5	80
2.6—3.0	75
3.1—3.5	71
3.6—4.0	45
4.2—4.5	27
4.5—5.0	30
5.1—5.5	11
5.6—6.0	2
6.0—7.0	0
7.0—8.0	0

The graph drawn from the above results in the form of histogram (Fig. 4), shows that percentage of spread-F becomes prominent as the critical frequency is lowered, and is thus a decreasing function of f_0. The same conclusion can be drawn from Fig. 2(a), showing the nature of variation of percent count of spread-F with the hourly average median f_0F_2. The ionograms for the summer months have only been taken for this analysis, as, during these days the missing records are least.

Variation of hourly median values of h_pF_2 and appearance of spread-F at Haringhata show that there is fairly parallel relationship between the two. Maximum of h_pF_2 coincides with the peak of the frequency of occurrence of spread-F (Fig. 3). The result supports those obtained by Kasuya *et al.* (1954) and Bowman (1960) and suggests that spread-F is originated from the upper F region.

(b) *Double F-traces and* (c) *Forked-F traces :* Night time $h'-f$ records sometimes contain two parallel F layer traces each showing the usual magnetoionic splitting with some degree of spreading. These are too close to each other to admit of any explanation in terms of multiple reflections. It is believed that the upper trace is due to oblique reflections from some moving folds or deformities in the F region.

Sometimes, instead of broadening, each of the two components of the F layer trace assumes a forked appearance near the critical frequency.

Typical examples of double-F and forked-F traces from our records are shown in Fig. 1(b) and 1(c).

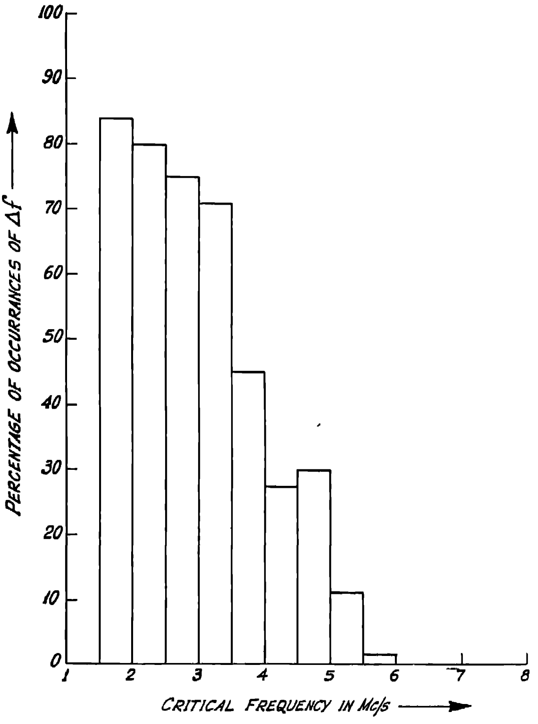

Fig. 4. Variation of percent count of occurrences of Spread-F with f_0F_2 for summer quiet days at Haringhata.

From the study of ionograms it is found that these are invariably associated with some degree of spreading either preceding or following the simple traces. Moreover, the diurnal variations of their occurrences for summer season (Fig. 5) follow the same pattern as that of the spread-F occurrence. This suggests that the causes of spread-F, double-F and forked-F traces are likely to be the same, the particular picture depending probably on the size and orientation of the said irregularities.

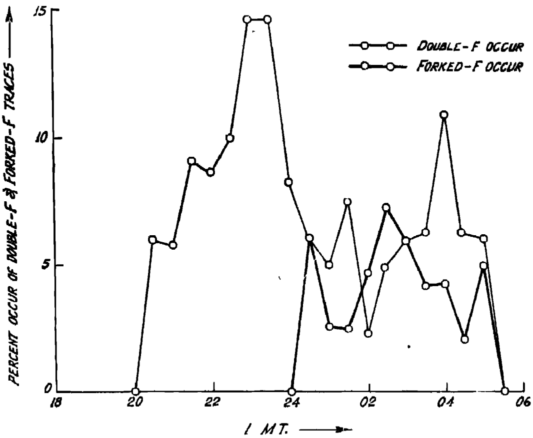

Fig. Diurnal variation of double-F and forked-F traces for summer seasons as found at Haringhata.

THEORETICAL INTERPRETATION OF OBSERVATIONAL RESULTS

A considerable amount of work has been done to explain the observed characteristics of the Spread-F phenomenon. According to the present state of knowledge, the most prominent cause of the phenomenon appears to be the irregularities which are known to exist in the electron density distribution in the F region. These irregularities have been found to correlate positively with magnetic activity at high latitudes and negatively at low latitudes. According to the above hypothesis Spread-F condition should exhibit similar correlation with magnetic activity. This indeed is what is found from the observations of Hertz (1959) and Lyon *et al.* (1958) and also from our result.

The effect of irregularities on the spread-F has been examined theoretically by Briggs. According to this author, the relation between the irregularity ΔN, the critical frequency f_0, and the spread Δf_0, is given by

$$\Delta N \propto f_0 \Delta f_0$$

Also, it has been shown by Voge (1955) that if v is the velocity with which the irregularity is drifted then ΔN is proportional to v^2. Hence, combining the above relation with Voge's proportionality

$$\Delta N \propto v^2$$

we may write
$$f_0 \Delta f_0 \propto v^2$$

or
$$\Delta f_0 \propto \frac{v^2}{f_0}, \; i.e., \; \frac{v^2}{\sqrt{N}}$$

This shows that the night-time increase in velocities of the irregularities and simultaneous decrease in electron density can intensify the degree of spreading. That the velocity changes considerably is well known from the measurement of drift movement by radio astronomical techniques. Drift speeds of 60 m/sec at 19 hr, 290 m/sec at 01 hr and 170 m/sec at 05 hr, have been recorded (Maxwell, 1954). Moreover, the decrease in electron density may cause the enhancement of scattering, for, such decrease in electron density reduces the electromagnetic damping of the turbulence on which the production of the irregularities depends (Booker, 1958). It has been suggested (Booker and Wells, 1938, Maxwell, 1954, Martyn, 1955 and Dagg 1957) that the irregularities may have their origin in the E layer turbulence created in the Dynamo region at night, the turbulence effect being communicated to the F region by the presence of earth's magnetic field. It is to be noted that v in the term v^2/f_0 varies considerably at the same place and also from place to place. This may explain the anomalies of the seasonal variations of spread-F occurrences at different places. Also, Δf_0 depends inversely on f_0. This inverse dependence may perhaps be associated with the observed relation of f_0F_2 and the percentage occurrence of spread-F.

CONCLUDING REMARK

Occurrence of spread-F is a night-time phenomenon and becomes more prominent at Haringhata during summer, during magnetically quiet days and during periods of low critical frequency. The observed results are in agreement with those obtained at equatorial stations like Ibandan, Singapore and Ahmedabad during low sunspot years. The change over latitude from the temperature type of spread to the equatorial type is not yet definitely known. Washington (Geomag. lat. 50°.3N) and Rarotonga (Geomag. lat. 21.7°S) may lie in the change over region. The anomaly of clear inverse correlation of spread-F occurrence with critical frequency at different places may be attributed to the possible fluctuations in the velocity of the irregularities. The ionograms, where the spread in critical frequency is measurable accurately (as in the case of weak spreading), may be used to estimate the velocity of the irregularities from the observed critical frequency and its spreading.

ACKNOWLEDGMENTS

The work forms part of the programme of the Radio Research Committee of the Council of Scientific and Industrial Research, Government of India. The author is indebted to Professor J. N. Bhar, D.Sc., F.N.I., for his keen interest and encouragement. Thanks are also due to Dr. A. K. Saha for valuable suggestions.

REFERENCES

Booker, H. G. and Wells, H. W., 1938, *Terr. Mag.*, **43**, 249.
Booker, H. G., 1956, *J. Geophys. Res.*, **61**, 673
Booker, H. G., 1956, *J. Atoms. Terr. Phys.*, S. Suppl. Part II. **52**.
Booker, H. G., 1958, *Proc. I R.E.*, **46**, 298.
Bowman, G. G., 1960, *Aust. J. Phys.*, **13**, 69.
Briggs, B. H., 1957, *J. Atoms Terr. Phys.*, **12**, 34.
Briggs, B. H., 1957, *J. Atmos. Terr. Phys*, **12**, 89.
Dagg, M., 1957, *J. Atmos. Terr. Phys.*, **11**, 133 & 139.
Eckersley, T. L., 1958, *Proc. Phys Soc.*, **56**, 1025.
Hartz, T R., 1959, *Canadian Jour. of Phys.*, **37**, 1137.
Kasuya, I., Kataho, S and Taguhi, S., 1955, *J R.R.L. (Japan)*, **2**, 329.
Katodia, K. M., 1959, *Proc. Ind. Acad. of Sciences*, L.
Lyon, A. J., Skinner, N. J. and Wright, R. W., 1958, *Nature*, **181**, 1724.
Maxwell, A., 1954, *Phil. Mag.*, **45**, 1247.
McNicol and Bowman, G. G., 1957, *Aust J. Phys.*, **10**, 588.
Rebor, G., 1954, *J. Geophys. Res* **59**, 257 & 445.
Voge, J., 1955, *L'Onde Electrique*, **35**, 565.
Wells, H. W., 1954, *J. Geophys. Res.*, **59**, 273.
Wright, R. W., Koster, J. R and Skinner, N. J., 1956, *J. Atmos. Terr. Phys.*, **8**, 240.

APPENDIX

If ρ is the density of air at the ionospheric region producing scattering and N is the number of electrons per unit volume then

$$N \propto \rho$$

Hence
$$\frac{\Delta N}{N} = \frac{\Delta \rho}{\rho} \quad \ldots \quad (1)$$

For perfect gas, where fluctuation of temperature is negligible it can be written that

$$\frac{\Delta \rho}{\rho} \simeq \frac{\Delta p}{p} \quad \ldots \quad (2)$$

where p is the pressure of air at that region.

The variation of atmospheric temperature with height during daytime and night-time (Fig. 6) shows that temperature gradient at night is comparatively low. So the Eqn. (2) is applicable in the ionospheric region at night.

Now $\Delta p \propto v^2$ (Bernouilli's principle).

$\Delta N \propto v^2$

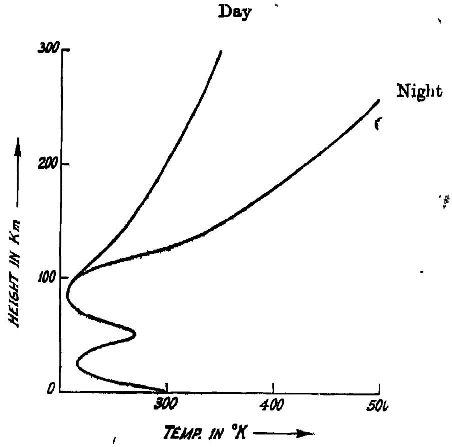

Fig. 6.